

2150 - 2800 nm coverage and diode pumping with ZnSe:Cr²⁺ lasers

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A diffraction grating allowed 2150 - 2800 tuning in a MgF₂:Co²⁺ - laser - pumped ZnSe:Cr²⁺ laser. Diode - side - pumping with a 1.65 μ m InGaAsP/InP array was also demonstrated.

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A new class of tunable mid-IR lasers has recently been revealed — Cr²⁺ - doped, tetrahedrally - coordinated II - VI compounds.¹ Spectroscopic evaluation² showed that Cr²⁺ has a high luminescence quantum yield and should be free of ESA. ZnSe and ZnS hosts gave laser action in a confocal cavity end-pumped with a focused, pulsed ~1900 nm MgF₂:Co²⁺ laser.^{1, 3} An intracavity birefringent filter gave 2280 - 2530 nm tunability centered around the gain maximum of ~2350 nm. Realization of the wide potential tuning range will enable various applications, including surgery with adjustable penetration depth owing to the rapidly - varying liquid water absorption coefficient. Other exciting development possibilities include laser - diode pumping, and short - pulse operation.

The laser design is influenced by the spectroscopic parameters (Table I.) Like Ti:sapphire, ZnSe:Cr²⁺ possesses similar electronic transition symmetry, short energy-storage lifetime (~9 μsec,) and broad emission linewidth. But, it has a drastically - smaller saturation intensity $I_{\text{sat}} = h\nu/\sigma\tau \sim 14 \text{ kW/cm}^2$ that enables efficient diode-pumped laser performance with 1.8 μm pump diode arrays delivering modest intensities of a few kW/cm². Side - pumping also eases the requirement (when end pumping) of pumping at or above I_{sat} .

A diode - side - pumped Nd:YVO₄ laser⁴ inspired our design (Figure 1,) in which the output of four microlensed 1.65 μm InGaAsP/InP diode bars is focused to a stripe on a ZnSe:Cr slab. The single bounce at the "TIR interface" exposes the resonated beam to the

high - gain pump face region, without causing aperture losses at the crystal ends. The diode array produced a maximum power of 75 W, at low duty cycle. Integrated - laser slope - efficiency data obtained with a series of flat output couplers showed the threshold energy increasing substantially for output - coupling values above 10%, reflecting a crystal passive loss estimated at $\alpha_{\text{loss}} \sim 15\%/ \text{cm}$. The 90% - reflecting output coupler maximized the peak output power at 0.34W. A ~6% "mode fill" (fraction of pump light absorbed in the resonated-mode volume) was estimated for this Cr²⁺ doping level, where the peak (1.8 μm) absorption coefficient was $\alpha_{\text{max}} \sim 4.4 \text{ cm}^{-1}$. The "figure of merit" $\text{FOM} \equiv \alpha_{\text{max}}/\alpha_{\text{loss}} \sim 27$ characterizes crystal quality, which we expect to improve.

During tuning experiments, a 420 line/mm diffraction grating replaced a cavity mirror, and a high - peak - power MgF₂:Co²⁺ laser beam substituted for the diode array. The apparent long - wavelength lasing limit (Figure 2) was ~2670 nm, but transparent CaF₂ substrates allowed output up to 2800 nm. Self - absorption from the long - wavelength tail of the pump band probably causes the ~2150 nm short - wavelength cutoff.

Our present research involves scaling a ZnSe:Cr²⁺ laser to Watt - level powers, and generating short pulses by passive Q - switching with a semiconductor saturable absorber; progress will be described.

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References

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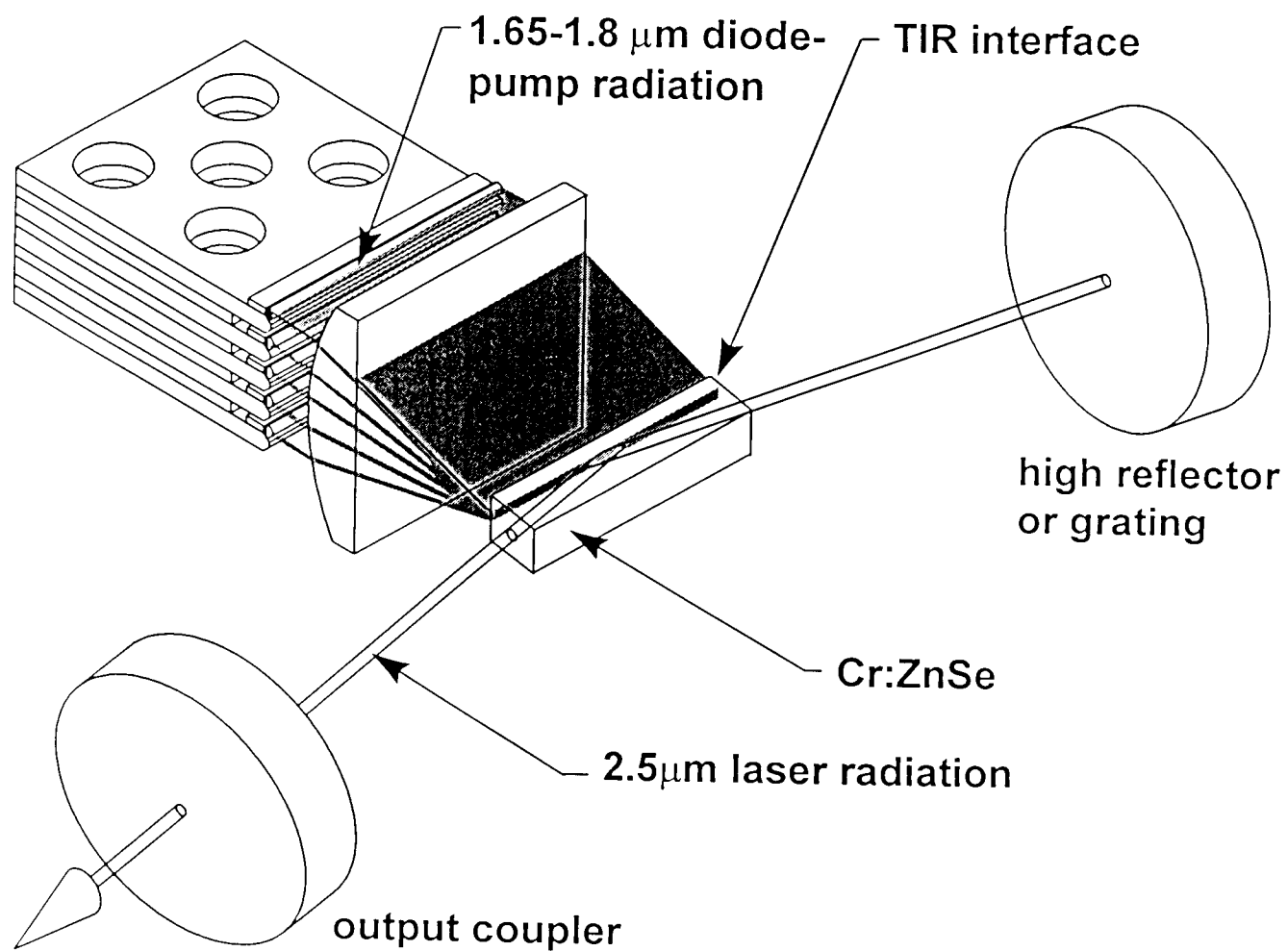
Figure Captions

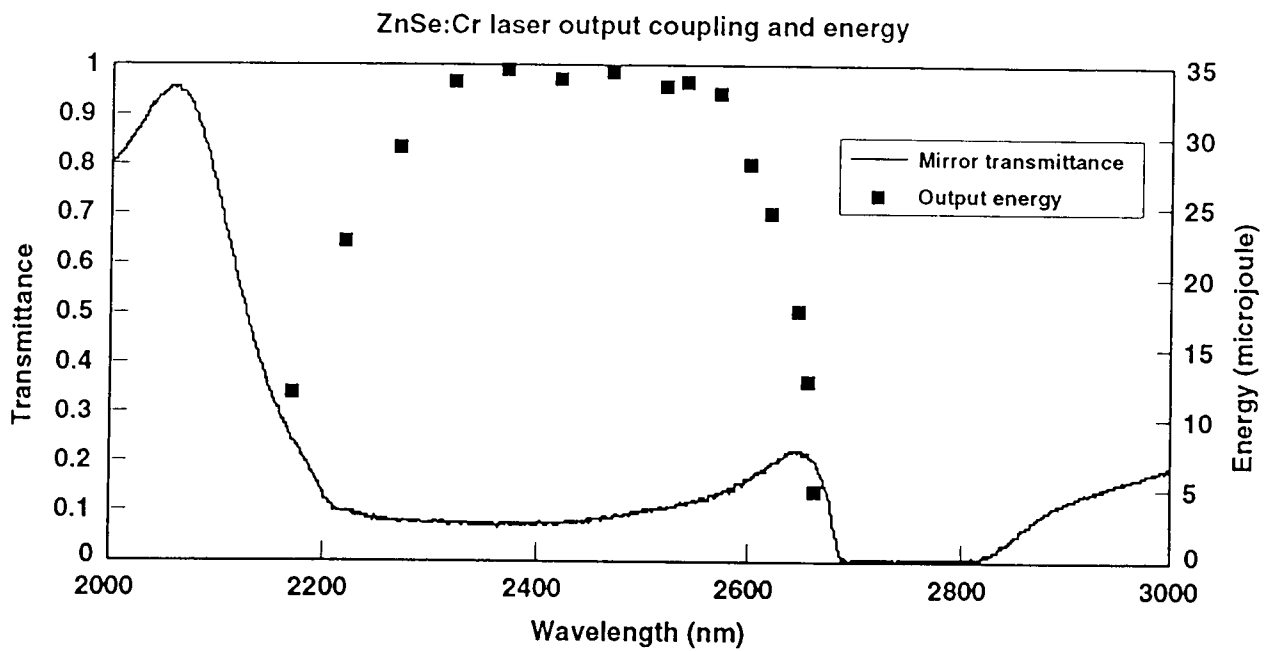
Table I. Comparison of spectroscopic properties of Al₂O₃:Ti³⁺ and II-VI:Cr²⁺; diode-pumped laser operation is enabled by the latter's much - lower **I_{sat}** value.

Fig. 1. Output stripe of a micro-lensed, multiple-bar "radiance - enhanced" diode array is well-coupled to the ZnSe:Cr slab in the side-pumped laser design.

Fig. 2. Tuning characteristics obtained with MgF₂:Co²⁺ laser pumping of ZnSe:Cr, resonated with a diffraction grating. The output-coupler transmittance spectrum reveals the OH absorption in the glass substrate material that blocked the laser's output from ~2650 - 2800 nm.

		Ti ³⁺ :Al ₂ O ₃	ZnSe:Cr ²⁺
Transition		² E → ² T ₂	⁵ E → ⁵ T ₂
Upper-level lifetime	τ _{em} (μsec)	3	9
Peak fluorescence wavelength	λ _{max} (nm)	800	2300
Fluorescence linewidth (RT)	Δν (cm ⁻¹)	4300	1700
	Δλ (nm)	300	1000
Relative bandwidth	Δλ/λ _{max}	0.38	0.43
Peak pump cross- section	σ _{abs} (10 ⁻²⁰ cm ²)	6.5	87
Pump saturation intensity	I _{sat} (kW/cm ²)	2000	14





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